Journal of Neonatal Surgery
ISSN(Online): 2226-0439
Vol. 14, Issue 32s (2025)
https://www.jneonatalsurg.com

Comparative Evaluation Of Efficacy Pertaining To Different Irrigation Regimes Viz. Ethylene-Diamine-Tetraacetic Acid, Peracetic Acid, Etidronic Acid, Distilled Water On The Push-Out Bond Strength Of Various Resin Based Sealers Like Adseal, Dia-Proseal, Epoxy-Seal, Rc Seal And Ah Plus, At Different Root Levels: An In Vitro Study

Dr. Shreeya Jaiswal[*1], Dr. Rana K Varghese[2], Dr. Raunak Singh[3], Dr. Ippar Priyanka Damodhar[4], Dr. Astha Dubey[5], Dr. Chawre Rashi Shridhar[6]

[*1]Postgraduate student, Department of Conservative Dentistry and Endodontics, New Horizon Dental College and Research Institute, Sakri, Bilaspur.
[2]Professor and HOD, Dean, Department of Conservative Dentistry and Endodontics, New Horizon Dental College and Research Institute, Sakri, Bilaspur.
[3]Reader, Department of Conservative Dentistry and Endodontics, New Horizon Dental College and Research Institute, Sakri, Bilaspur.
[4]Post graduate student, Department of Conservative Dentistry and Endodontics, New Dental College and Research Institute, Sakri, Bilaspur.
[5]Post graduate student, Department of Conservative Dentistry and Endodontics, New Horizon Dental College and Research Institute, Sakri, Bilaspur.
[6]Post graduate student, Department of Conservative Dentistry and Endodontics, New Horizon Dental College and Research Institute, Sakri, Bilaspur.
[*]**Corresponding author:**
Dr. Shreeya Jaiswal

.Cite this paper as: Dr. Shreeya Jaiswal, Dr. Rana K Varghese, Dr. Raunak Singh, Dr. Ippar Priyanka Damodhar, Dr. Astha Dubey, Dr. Chawre Rashi Shridhar, (2025) Comparative Evaluation Of Efficacy Pertaining To Different Irrigation Regimes Viz. Ethylene-Diamine-Tetraacetic Acid, Peracetic Acid, Etidronic Acid, Distilled Water On The Push-Out Bond Strength Of Various Resin Based Sealers Like Adseal, Dia-Proseal, Epoxy-Seal, Rc Seal And Ah Plus, At Different Root Levels: An In Vitro Study. *Journal of Neonatal Surgery*, 14 (32s), 5874-5884.

ABSTRACT

Aim: This study aims for comparative evaluation of the efficacy of EDTA, PAA, HEBP, Distilled water on push-out bond strength of Resin based sealers at three different root levels of endodontically treated mandibular premolars.

Materials and methods: The study utilized 100 freshly extracted mandibular single-rooted premolars collected from patients aged 20–45 years through the Department of Oral and Maxillofacial Surgery and dental outreach camps of New Horizon Dental College and Research Institute, Bilaspur. Teeth extracted for orthodontic reasons and meeting inclusion criteria—single canals, intact apices, no caries, cracks, restorations, or severe anatomic variations—were cleaned and stored in normal saline. After decoronation at the cementoenamel junction to standardize length to 15 mm, access cavities were prepared, and working lengths were determined using an apex locator. Root canal instrumentation was carried out using Protaper Universal rotary files up to size F3.

Results: The current study revealed a significant impact by the chemicals contained in irrigating solutions on bond strength to dentine in a push-out test of an epoxy resin sealer. Furthermore, sealing ability and bond strength strongly correlated with each other.

Conclusion: Mandibular premolars were tested in this study to evaluate the Push-Out Bond Strength of various sealers. AH Plus sealer, regarded as the gold standard, consistently showed superior bond strength across all root levels. Epoxy sealers outperformed Adseal, Dia-Proseal, and RC Seal in this aspect. Among the irrigation agents, EDTA and HEBP demonstrated significantly higher bond strength compared to PAA and distilled water, with AH Plus consistently exhibiting better performance than all other sealers. Notably, AH Plus showed the highest bond strength at the apical third, followed by the coronal and then the middle third. In contrast, EpoxySeal, Adseal, Dia-Proseal, and RC Seal displayed the highest bond strength at the apical third, followed by the middle and least at the coronal third. These findings highlight the superior efficacy of EDTA and HEBP, particularly in enhancing the apical bond strength of AH Plus, suggesting the need for further long-term clinical studies using similar irrigation protocols and sealers to confirm these results

Keywords: *Sealer, Resin, EpoxySeal*

1. INTRODUCTION

Root canal treatment involves several critical steps—accessing the infected pulp, cleaning and shaping the canal, disinfecting it, and sealing the space to prevent reinfection. A key component in achieving long-term success in endodontics is the use of endodontic sealers, which help ensure a tight seal between the gutta-percha and dentin walls. Gutta-percha alone does not adhere to the canal walls, so sealers are essential to prevent bacterial leakage, support antimicrobial activity, and promote healing.[1,2,3]

Among the different types of sealers available, resin-based sealers are popular due to their excellent sealing ability, biocompatibility, dimensional stability, and antimicrobial properties. These sealers typically include resin monomers, fillers, initiators, plasticizers, thickeners, and radio-opacifiers. They offer strong adhesion to dentin and gutta-percha, making them durable and resistant to leakage, with a fast setting time and ease of application.[4,5,6]

Some of the commonly used resin-based sealers include AH Plus, EpoxySeal, ADSEAL, DIA-PROSEAL, and RC Seal. These sealers differ slightly in composition but generally provide strong bonding, radiopacity, antimicrobial effects, and compatibility with obturation techniques. Their effectiveness largely depends on their interaction with the dentin surface, which may be compromised by the presence of a smear layer formed during biomechanical preparation.[7,8]

The smear layer, consisting of both organic and inorganic debris, impairs the bond between sealers and dentin by blocking sealer penetration into dentinal tubules. Thus, effective smear layer removal through irrigation is essential to improve the push-out bond strength of sealers. Sodium hypochlorite (NaOCl), though commonly used, cannot dissolve inorganic material, prompting the use of chelating agents such as EDTA, peracetic acid (PAA), and etidronic acid (HEBP) for complete smear layer elimination.[9,10]

Each irrigant offers distinct advantages: EDTA (15–17%) and PAA (1–2.25%) exhibit strong chelating and antimicrobial properties, while HEBP (9–18%) offers low toxicity and compatibility with other irrigants. Distilled water is sometimes used as a final rinse to eliminate residual chemicals and debris, enhancing the effectiveness of subsequent obturation.[11,12]

To evaluate how these irrigation regimes affect the bonding performance of resin-based sealers, push-out bond strength testing was conducted. This involved applying compressive loads using a universal testing machine (Instron) at different root levels, measuring the force required to dislodge the sealer in megapascals (MPa). Comparing these values across different sealers and irrigation combinations provided insights into optimal clinical practices for improving endodontic outcomes.

2. MATERIALS AND METHODS

The study utilized 100 freshly extracted mandibular single-rooted premolars collected from patients aged 20–45 years through the Department of Oral and Maxillofacial Surgery and dental outreach camps of New Horizon Dental College and Research Institute, Bilaspur. Teeth extracted for orthodontic reasons and meeting inclusion criteria—single canals, intact apices, no caries, cracks, restorations, or severe anatomic variations—were cleaned and stored in normal saline. After decoronation at the cementoenamel junction to standardize length to 15 mm, access cavities were prepared, and working lengths were determined using an apex locator. Root canal instrumentation was carried out using Protaper Universal rotary files up to size F3.

The 100 teeth were randomly divided into four experimental groups (n = 25 each) based on the final irrigation regimen used: Group I – 5% NaOCl + 17% EDTA, Group II – 5% NaOCl + 2.25% PAA, Group III – 5% NaOCl + 18% HEBP, and Group IV – distilled water (control). During canal preparation, 1 ml of 5% NaOCl was used at each instrument change for Groups I to III. All irrigants were activated ultrasonically. Final irrigation was performed with 1 ml of the respective chelating solution or distilled water.

Each group was further subdivided into five subgroups (n = 5 each) based on the sealer used for obturation with gutta-percha: Subgroup A – AH Plus, Subgroup B – DIA-PROSEAL, Subgroup C – EpoxySeal, Subgroup D – ADSEAL, and Subgroup E – RC Seal. The obturated samples were stored in 100% humidity at 37°C for one week to allow for complete sealer setting. After incubation, each root was sectioned horizontally to produce 2 mm thick slices at coronal, middle, and apical levels for bond strength testing.

The push-out bond strength was measured using a Universal Testing Machine at a cross-head speed of 2 mm/min. Plungers of different diameters (1 mm for coronal, 0.8 mm for middle, and 0.3 mm for apical slices) were used according to root level. Bond strength in megapascals (MPa) was calculated by dividing the maximum load (N) by the bonding surface area, determined using the formula for the lateral surface area of a conical frustum: Area = $\pi (R1 + R2) \times \sqrt{(R1 - R2)^2 + H^2}$, where *H* is the slice height, and *R1* and *R2* are the internal radii of the wider and narrower ends, respectively.

3. RESULTS

Table 01: Showing study involving 4 groups containing 25 samples each, which is further subdivided into 20 samples each are as follows:

Group	**Irrigants**
Group 1	5 % NaOCl followed by 17% EDTA;
Group 2	5 % NaOCl followed by 2.25% PAA;
Group 3	5 % NaOCl followed by 18% Etidronic Acid / HEBP;
Group 4	Distilled water (Control);

Push-out bond strength testing was conducted using a computerized Universal Testing Machine (Model No. UNITEST-10, ACME Engineers, Pune) with ±1% accuracy and a cross-head speed of 2 mm/min. Testing was performed at Praj Dental Laboratory, Pune. Plunger diameters were selected based on root section: 1 mm for the coronal third (area = 7.53 mm^2), 0.8 mm for the middle third (area = 6.91 mm^2), and 0.3 mm for the apical third (area = 6.28 mm^2). Bond strength (MPa) was calculated using the formula: Push-out strength = maximum load (N) / bonding surface area, with area derived from the conical frustum formula: Area = $\pi(R1 + R2)\sqrt{(R1 - R2)^2 + H^2}$, where H is the slice height, R1 the larger internal radius, and R2 the smaller. The samples were categorized under four main groups based on irrigation regimens (Group I – NaOCl + EDTA, Group II – NaOCl + PAA, Group III – NaOCl + HEBP, and Group IV – distilled water control), each further subdivided into five subgroups based on the type of sealer used with gutta-percha (Subgroup A – AH Plus, B – DIA-PROSEAL, C – EpoxySeal, D – ADSEAL, and E – RC Seal). Push-out bond strength was recorded for each specimen at the coronal, middle, and apical thirds, reflecting the combined influence of irrigation regimens and sealers on bonding efficacy.

Table 2: Pushout bond strength of samples irrigated with different irrigation regimen and obturated with AH plus sealer.

Sealer	**AH plus**				
Irrigant	**Sample 1**	**Sample 2**	**Sample 3**	**Sample 4**	**Sample 5**
EDTA					
Cervical	3.73	3.74	3.74	3.7	3.72
Middle	3.65	3.69	3.6	3.6 3	3.67
Apical	4.68	4.49	4.53	4.54	4.59
HEBP					
Cervical	3.67	3.69	3.68	3.62	3.67
Middle	3.52	3.49	3.45	3.46	3.38
Apical	4.38	4.33	4.28	4.18	4.26
PAA					
Cervical	3.4	3.43	3.38	3.27	3.44
Middle	3.21	3.24	3.23	3.22	3.28
Apical	3.79	3.78	3.67	3.54	3.62
Distal. Water					
Cervical	2.54	2.56	2.58	2.51	2.43
Middle	2.29	2.33	2.32	2.33	2.34
Apical	3.5	3.43	3.38	3.49	3.47

Table -03: Pushout bond strength of samples irrigated with different irrigation regimen and obturated with EpoxySeal sealer;

Sealer	**EpoxySeal**				
Irrigant	**Sample- 1**	**Sample- 2**	**Sample- 3**	**Sample- 4**	**Sample- 5**
EDTA					
Cervical	3.11	3.17	3.09	3.12	3.15
Middle	3.54	3.59	3.53	3.56	3.52
Apical	4.03	4.02	4.05	4.08	4.07
HEBP					
Cervical	3.05	3.08	3.02	3.04	3.01
Middle	3.4	3.45	3.43	3.42	3.46
Apical	3.99	3.98	3.93	3.94	3.9
PAA					
Cervical	**2.75**	2.76	2.7	2.79	2.75
Middle	2.9	2.87	2.84	2.88	2.89
Apical	3.49	3.13	3.18	3.15	3.17
Distal. Water					
Cervical	**2.12**	2.17	2.15	2.13	2.11
Middle	2.43	2.47	2.45	2.41	2.41
Apical	3.19	3.13	3.18	3.15	3.17

Table -04: Pushout bond strength of samples irrigated with different irrigation regimen and obturated with ADSEAL sealer;

Sealer	**ADSEAL**				
Irrigant	**Sample- 1**	**Sample- 2**	**Sample- 3**	**Sample- 4**	**Sample- 5**
EDTA					
Cervical	2.91	2.9	2.93	2.94	2.98
Middle	3.45	3.47	3.48	3.5	3.43
Apical	3.93	3.87	3.9	3.92	3.95
HEBP					
Cervical	2.8	2.88	2.83	2.84	2.87

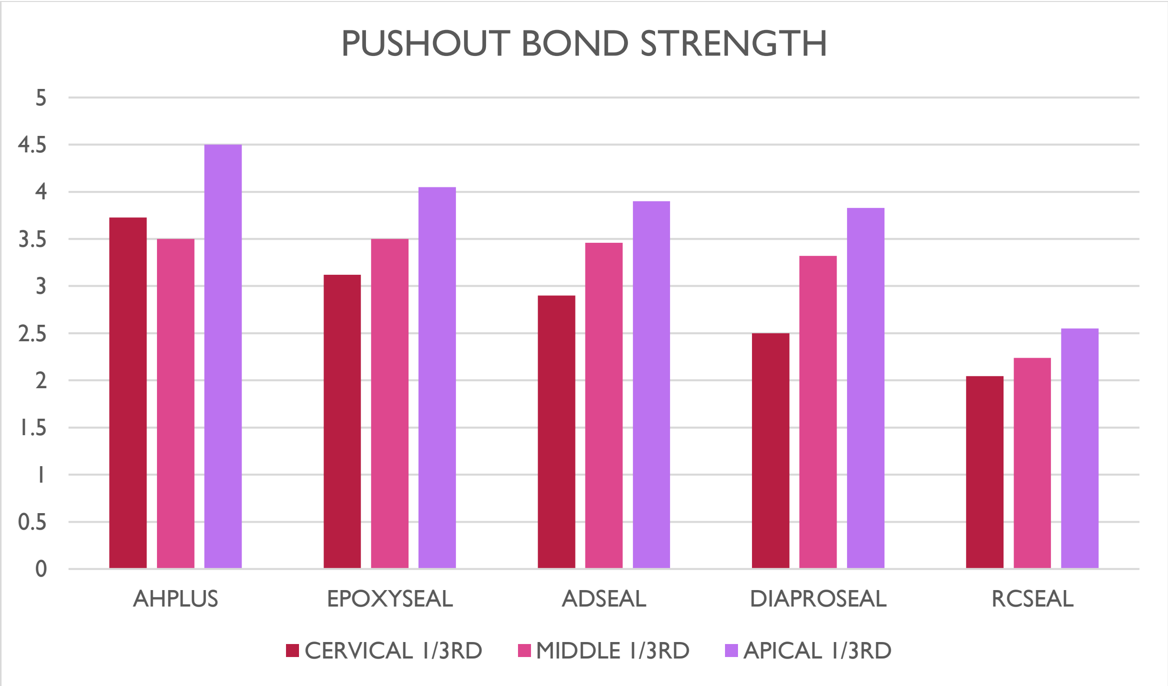
Middle	3.93	3.87	3.9	3.92	3.95
Apical	3.84	3.89	3.85	3.82	3.87
PAA					
Cervical	2.54	2.51	2.53	2.5	2.59
Middle	2.64	2.67	2.63	2.31	2.65
Apical	3.38	3.37	3.3	3.39	3.35
Dist. Water					
Cervical	2.09	2.07	2.05	2.03	2.04
Middle	2.32	2.27	2.3	2.39	2.25
Apical	2.89	2.9	2.84	2.99	3.01

Table -05: Pushout bond strength of samples irrigated with different irrigation regimen and obturated with DIA PROSEAL sealer;

Sealer	**DIAPROSEAL**				
irrigant	**Sample 1**	**Sample 2**	**Sample 3**	**Sample 4**	**Sample 5**
EDTA					
Cervical	2.57	2.58	2.59	2.5	2.53
Middle	3.32	3.3	3.31	3.34	3.33
Apical	3.82	3.8	3.81	3.87	3.85
HEBP					
Cervical	2.46	2.53	2.58	2.59 2	2.51
Middle	3.12	3.13	3.14	3.17	3.2
Apical	3.54	3.58	3.57	3.5	3.53
PAA					
Cervical	2.23	2.25	2.27	2.3	2.28
Middle	2.39	2.34	2.35	2.31	2.32
Apical	3.16	3.17	3.15	3.2	3.18
Dist. Water					
Cervical	1.9	1.93	1.96	1.87	1.81
Middle	2.19	2.25	2.28	2.3	2.22
Apical	2.77	2.8	2.73	2.67	2.75

Table -06: Pushout bond strength of samples irrigated with different irrigation regimen and obturated with RC Seal sealer;

Sealer	**RC Seal**				
Irrigant	**Sample 1**	**Sample 2**	**Sample 3**	**Sample 4**	**Sample 5**
EDTA					
Cervical	2.02	2.07	2.08	2.05	2.01
Middle	2.28	2.27	2.25	2.21	2.22
Apical	2.58	2.51	2.59	2.53	2.57
HEBP					
Cervical	1.92	1.87	1.93	1.91	1.9
Middle	2.11	2.12	2.19	2.2	2.21
Apical	2.45	2.47	2.43	2.39	2.31
PAA					
Cervical	1.67	1.49	1.53	1.64	1.68
Middle	2.01	2.06	1.96	1.99	2
Apical	2.34	2.32	2.39	2.28	2.31
Dist. Water					
Cervical	1.19	1.17	1.11	1.09	1.15
Middle	1.82	1.85	1.8	1.87	1.79
Apical	2.2	2.11	2.25	2.19	2.23



4. DISCUSSION

Ensuring that root canal filling material adheres to the dentinal walls is a highly desirable physical feature for the long-term clinical efficacy of endodontic therapy, as it prevents fluid from percolating between the regions of obturation [13] . Endodontic sealers aid in adhesion to root canal dentin, preserving the integrity of the sealer-dentin interface, and prevent dislodgement. The main objective of root canal obturation is to create a strong bond between filling materials and dentinal walls[14] . This is achieved by combining a solid obturation substance with an endodontic cement that binds to dentin and maintains dimensional stability for a hermetic seal. The Push Out Bond Strength of root canal sealers is an important factor to consider in an endodontic treatment [15]. The adhering ability of a sealer to the root canal walls can influence the success of the root canal treatment by preventing microleakage and bacterial penetration.

The present study was designed to examine the effect of 17% EDTA, 18% Etridonic acid, Distilled water and 2.25 % Peracetic acid on the sealing ability and push-out bond strength of various root canal sealer to root dentine. The null hypotheses tested were: (1) there was no difference in the efficacy of different irrigants on the push-out bond strength of various sealers at different root levels, (2) there was no difference in the push-out bond strength of various sealers. and, (3) there was no difference in the push-out bond strength measured at three different root levels. The first null hypothesis was rejected as, there was difference in the efficacy of different irrigants on the push-out bond strength of various sealers at different root levels. The second null hypothesis was also rejected as, there was difference in the push-out bond strength of various sealers. The third null hypothesis was too rejected that, there is difference in the push-out bond strength measured at three different root levels: apical, middle and coronal.

The current study revealed a significant impact by the chemicals contained in irrigating solutions on bond strength to dentine in a push-out test of an epoxy resin sealer. Furthermore, sealing ability and bond strength strongly correlated with each other. Adhesion is a clinically desirable property of root canal sealers. Ideally, these materials should not shrink and bond effectively to both the surrounding substrates: the root canal walls and the core root-filling material (Grossman 1976)[2] . Upon introduction of adhesive root-filling materials, it was claimed that methacrylate-based sealers, which are rooted in adhesive technology developed for restorative dentistry and thus aimed to adhere to coronal dentine100, could minimize leakage by increasing the seal between the core root-filling material and the root canal walls (Schwartz 2006).

In this study, the push-out test method was used to test the dentine bond strengths of different root canal sealers. Extrusion testing in dentistry was first described by Roydhouse (1970). Kimura (1985) concluded that push-out testing tended to reduce the values for bond strength to dentine. Haller et al. (1991) re-introduced the push-out test and the testing procedure selected for the present investigation used that model[16]. The model has been shown to be effective and reproducible (Haller et al. 1993). Another advantage of this method is that it allows root canal sealers to be evaluated even when bond strengths are low. During chemo-mechanical preparation, a layer of debris, the smear layer, is formed. Current theories of dentine bonding mechanisms involve either chemical modification of the smear layer and bonding directly to it, or removal of the smear layer and bonding to subjacent tooth structures (Yu et al. 1993). Some studies have shown that removal of the smear layer enhances the adhesion of sealers to the root canal walls (De Gee et al. 1994, Pecora et al. 2001).

The smear layer can act as a reservoir or substrate for microorganisms (Pashley 1984), and can also block the extension of sealer tags into the dentinal tubules[17] , thereby decreasing micromechanical adhesion (Kouvas et al. 1998). In the current study, 17% EDTA was used during and after instrumentation to remove the smear layer. All five of the groups tested showed measurable adhesive properties[18] . Wang et al. stated that despite the kind of sealers or obturation techniques used, the sealer penetration percentages into the dentinal tubules of the root canal increases from the apical to the coronal part due to the amount of eliminated smear layer in the coronal portion of the root canal. Moreover, dentin in the coronal, intermediate, and apical portions has variable surface energies, in conjunction with challenges experienced during the complete removal of the smear layer from the apical region.

The current study produced results that merit discussion. First and foremost, application of a decalcifying agent improved bond strength and sealing ability of the epoxy resin root canal sealer under investigation – AH Plus103. There is but one logical explanation for this result: AH Plus is able to bond to the organic phase of the root dentine, most likely in the collagen network. However, this effect was abolished when sodium hypochlorite was applied subsequently as the final irrigating solution. The point is that a final NaOCl flush after EDTA has been recommended based on the appearance of root canal walls after cleaning and shaping, and final irrigation (Yamada et al. 1983, Baumgartner & Mader 1987). A final sodium hypochlorite flush.

has two effects, which may be responsible for the decrease in epoxy resin bond strength to dentine and the resulting increase in leakage[19]. First, sodium hypochlorite will remove organic material from the exposed dentine surface (Marending et al. 2007). Second, sodium hypochlorite breaks down to sodium chloride and oxygen. Oxygen causes strong inhibition of the interfacial polymerization of methacrylate resins (Munksgaard et al. 1985). The polyaddition reaction during the curing of epoxy resins, however, is not affected by oxygen. On the other hand, the generation of oxygen bubbles at the resin–dentine interface may directly interfere with resin infiltration into the tubules[20] . In the present study, endodontic irrigation syringe with Ultra sonic Irrigation System was used. The rate of flow for each irrigant was standardized to 1 ml/30 s of time period. In our study EDTA showed higher bond strength, which is in concurrence with previous studies that have employed NaOCl followed by 17% EDTA as final irrigants[21,22] . EDTA showed higher bond strength followed by HEBP, the possible reason might be due to the removal of smear layer. Smear layer removal procedures allow the sealer penetration into the dentinal tubules and thus could increase the dentin bond strength of resin-based sealer as well as an enhanced seal.[21],[23] .Other possible reason might be the depth of demineralized zone, which is a critical factor. Garcia-godoy et al,[24]showed that the EDTA created demineralized dentin zone about 2- 4µm deep. Being a soft chelating agent, HEBP creates demineralized dentin zone less compared to EDTA.

Among the irrigants, 17% EDTA demonstrated the highest push-out bond strength values followed by 18% HEBP, 2.25% PAA, and Distilled water with all the sealers at all the root levels[25]. However, the difference between EDTA and HEBP was not statistically significant, whereas other irrigants showed significant differences at all root levels. This could be attributed to the fact that 17% EDTA effectively removed the smear layer that allowed the penetration of the resin into the open dentinal tubules, hence, creating an efficient microretention[26,27]. Hashem et al. and Neelakantan et al. [28] found out that the surface treatment with 17% EDTA favors the adhesion of resinous AH Plus. Since 18% Etidronic acid is a soft chelating agent and produces less depth of demineralized dentin, it facilitates the complete infiltration of resins through exposed collagen fibers.[28]Therefore, this reason might have possibly resulted in comparable bond-strength values between EDTA and HEBP in this study. In accordance to the current findings, Kandaswamy et al. [27] found nonsignificant differences between 18% HEBP and 17% EDTA when used with AH Plus sealer.

Peracetic acid (PAA), has been widely used for disinfecting medical equipment, among other items. It is fast and effective against bacteria, fungi, spores, and viruses, even in the presence of organic matter.[29,30,31] PAA has been used as single endodontic irrigant throughout eastern Europe. A recent study showed that when used as a single endodontic irrigant, 1% PAA shows an antibacterial efficacy similar to that of 2.5% NaOCl and 2% chlorhexidine against Enterococcus faecalis.[30] Another study showed that 4% PAA kills and dissolves significantly mixed biofilms in a manner similar to that of 2.5% and 5.25% NaOCl.48 In addition to its antibacterial effectiveness, PAA has the capacity to remove the smear layer when used as a final rinse after the use of NaOCl.[31,32]Its antibacterial effectiveness associated with its capacity for removing the smear layer has made PAA a possible alternative to be used as single irrigant, which would simplify and speed up root canal preparation. Nevertheless, while PAA presents the potential for use as a root canal irrigant[33] , there is no evidence of its effect on the cleaning of the root canal and of the quality of the endodontic filling following its use. In this study among irrigants, 2.25% PAA showed inferior push-out bond strength values because of its highly acidic pH (pH = 2.5), which resulted in more calcium elution from the root canal dentine. Taneja et al. [34] reported that irrigation with 2.25% PAA caused the highest calcium loss from the root dentin that resulted in reduced microhardness when compared with 17% EDTA.

The smear layer formed during root canal preparation is composed of both inorganic and organic substances that may also contain bacteria and their by-products. The smear layer may prevent intracanal medications from penetrating into the root canal system and influence the adaptation, bond,[35,36] and penetrability of root canal sealers into root dentin. [37] The protocol most commonly used for removing the smear layer is the alternate use of NaOCl and EDTA. The lowest push-out bond strength values were evident in control group (Distilled water), in which the smear layer was kept intact indicating the negative effects of undisturbed smear layer on push-out bond strength values.

However, it has been shown that epoxy resin cements such as AH Plus, Epoxy Seal, Adseal, Dia-proseal, and RC Seal have higher bond strength to root dentine than methacrylate sealers (Gesi et al. 2005, De-Deus et al. 2009)[38]. Furthermore, epoxy resin sealers have higher bond strength to the core filling material than other types of sealers (Lee et al. 2002). Methacrylatebased root canal sealers undergo significant volumetric shrinkage during the polymerization process (Souza et al. 2009). Epoxy resin sealers, in contrast, do not shrink when they cure (Orstavik et al. 2001, Souza et al. 2009). Interestingly, there appears to be an impact of irrigating protocols on the adhesion of sealers to root dentine (De-Deus et al. 2008, Nunes et al. 2008, Pinna et al. 2009). Epoxy resin sealers have been used because of their reduced solubility apical seal and micro-retention to root dentine.

It has been theorized that the adhesiveness of epoxy resin-based sealers to root dentine is related to covalent bonds between epoxide rings and the exposed amino groups in the collagen network (Fisher et al. 2007). Consequently, it could be so that the collagen network needs to be exposed and minimally preserved to improve bond strength (Nunes et al. 2008). Root dentine is differentially affected by calcium chelating agents and the proteolytic sodium hypochlorite (Mai et al. 2010, Zhang et al. 2010). The type of decalcifying agent has a significant impact on the root dentine wall: EDTA will cause a complete demineralization of the exposed wall, whilst organic acids cause a mineral gradient (Lottanti et al. 2009). The latter dentine condition could yield itself better to resin infiltration (Prati et al. 1990). The treatment goal remains to prevent oral pathogens from colonising and re-infecting the root and periapical tissues and to thereby maintain long-term periapical health.[39]

Among all the five sealers, the highest push-out bond strength values were shown by AH Plus followed by Epoxy Seal, followed by Adseal, Diaproseal and the least was found in RC Seal with all the irrigants at all root thirds, and the differences between all three of them were statistically significant. The possible reason for the higher values of AH Plus could be attributed to its inherent volumetric expansion property that resulted in the formation of a covalent bond between sealer and exposed amino groups of root dentin by an open epoxide ring that showed photopolymerization.[37,40] In a study Rahimi et al. [41]found out that epoxy resin-based sealers showed higher bond strength values.

In the present study, apical third showed significantly higher push-out bond strength value followed by cervical and middle for AH plus sealer. Although the tubule density decreases from coronal to apical region, the circular cross-section of root canal at apical third might had provided higher resistance to dislodgment forces during the testing. On the other hand, coronal and middle portion has oval or even flattened root canal sections88. These variations in the root canal anatomy might lead to misfit of the main gutta-percha and lead to impaired bond strength.

Baldissera et al. [42] compared the effects of different irrigants on sealer-dentin bond strength when using RealSeal and stated that higher bond strength was observed in apical portion in comparison to coronal and middle regions. Contrary to this, clinical trials by Paque et al. (2006),[43] Lottanti et al. [20] reported the highest bond strength in the coronal region in comparison to apical region. The possible explanation for such contrasting findings might be because of the use of positive pressure irrigation technique in their studies.

5. CONCLUSION

Mandibular premolars were tested in this study to evaluate the Push-Out Bond Strength of various sealers. AH Plus sealer, regarded as the gold standard, consistently showed superior bond strength across all root levels. Epoxy sealers outperformed Adseal, Dia-Proseal, and RC Seal in this aspect. Among the irrigation agents, EDTA and HEBP demonstrated significantly higher bond strength compared to PAA and distilled water, with AH Plus consistently exhibiting better performance than all other sealers. Notably, AH Plus showed the highest bond strength at the apical third, followed by the coronal and then the middle third. In contrast, EpoxySeal, Adseal, Dia-Proseal, and RC Seal displayed the highest bond strength at the apical third, followed by the middle and least at the coronal third. These findings highlight the superior efficacy of EDTA and HEBP, particularly in enhancing the apical bond strength of AH Plus, suggesting the need for further long-term clinical studies using similar irrigation protocols and sealers to confirm these results

REFERENCES

[1] Diksha Verma, Sonali Taneja, and Manju Kumari. Efficacy of different irrigation regimes on the push-out bond strength of various resin-based sealers at different root levels: An in vitro study; J Conserv Dent. 2018;

[2] Grossman L. 10th ed. Philadelphia (PA): Henry Kimpton Publishers; 1981. Endodontic Practice.

[3] De-Deus G, Di Giorgi K, Fidel S, Fidel RA, Paciornik S. Push-out bond strength of resilon/Epiphany and resilon/Epiphany self-etch to root dentin. J Endod. 2009;

[4] Prado M, Gusman H, Gomes BP, Simão RA. Scanning electron microscopic investigation of the effectiveness of phosphoric acid in smear layer removal when compared with EDTA and citric acid. J Endod. 2011;

[5] Kuçi A, Alaçam T, Yavaş O, Ergul-Ulger Z, Kayaoglu G. Sealer penetration into dentinal tubules in the presence or absence of smear layer: A confocal laser scanning microscopic study. J Endod. 2014;40:1627–31.

[6] Sagsen B, Ustün Y, Demirbuga S, Pala K. Push-out bond strength of two new calcium silicate-based endodontic sealers to root canal dentine. Int Endod J. 2011;44:1088–91. Goldman M, Goldman LB, Cavaleri R, Bogis J, Lin PS. The efficacy of several endodontic irrigating solutions: A scanning electron microscopic study: Part 2. J Endod. 1982.

[7] Zehnder M, Schmidlin P, Sener B, Waltimo T. Chelation in root canal therapy reconsidered. J Endod. 2005;

[8] Raina R., et al., Evaluation of the quality of the apical seal in Resilon/Epiphany and Gutta-Percha/AH Plus–filled root canals by using a fluid filtration approach. Journal of endodontics, 2007. 33(8): p. 944–947.

[9] Desai S. and Chandler N., Calcium hydroxide–based root canal sealers: a review. Journal of endodontics, 2009. 35(4): p. 475–480.

[10] Zehnder M, Schicht O, Sener B, Schmidlin P. Reducing surface tension in endodontic chelator solutions has no effect on their ability to remove calcium from instrumented root canals. J Endod. 2005.

[11] Stelzer R, Schaller HG, Gernhardt CR. Push-out bond strength of RealSeal SE and AH Plus after using different irrigation solutions. J Endod. 2014 Oct;40(10):1654-7. doi: 10.1016/j.joen.2014.05.001. Epub 2014 Jul 12. PMID: 25260739..

[12] Sagsen B, Ustün Y, Demirbuga S, Pala K. Push-out bond strength of two new calcium silicate-based endodontic sealers to root canal dentine. Int Endod J. 2011 Dec;44(12):1088-91. doi: 10.1111/j.1365-2591.2011.01925.x. Epub 2011 Sep 5. PMID: 21895700.

[13] Bodrumlu E, Parlak E, Bodrumlu EH. The effect of irrigation solutions on the apical sealing ability in different root canal sealers. Braz Oral Res. 2010 Apr-Jun;24(2):165-9.

[14] Sethi S, Bhushan J, Joshi RK, Singla R, Sidhu K. Effect of different irrigants on the push-out bond strength of biodentine and TheraCal LC when used for perforation repair in simulated condition. J Conserv Dent. 2023 May-Jun;26(3):321-325.

[15] De-Deus G, Di Giorgi K, Fidel S, Fidel RA, Paciornik S. Push-out bond strength of resilon/Epiphany and resilon/Epiphany self-etch to root dentin. J Endod. 2009;35:1048–50.

[16] Scelza MZ, da Silva D, Scelza P, de Noronha F, Barbosa IB, Souza E, De Deus G. Influence of a new push-out test method on the bond strength of three resin-based sealers. Int Endod J. 2015 Aug;48(8):801-6.

[17] Mozayeni MA, Zadeh YM, Paymanpour P, Ashraf H, Mozayani M. Evaluation of push-out bond strength of AH26 sealer using MTAD and combination of NaOCl and EDTA as final irrigation. Dent Res J (Isfahan). 2013 May;10(3):359-63.

[18] Leal F, Simão RA, Fidel SR, Fidel RA, do Prado M. Effect of final irrigation protocols on push-out bond strength of an epoxy resin root canal sealer to dentin. Aust Endod J. 2015 Dec;41(3):135-9.

[19] Fundaoğlu Küçükekenci F. The effect of different acidic irrigation solutions on the pushout bond strength of root canal filling. J Dent Res Dent Clin Dent Prospects. 2023 Winter;17(1):18-22.

[20] Neelakantan P, Varughese AA, Sharma S, Subbarao CV, Zehnder M, De-Deus G. Continuous chelation irrigation improves the adhesion of epoxy resin-based root canal sealer to root dentine. Int Endod J. 2012 Dec;45(12):1097-102.

[21] Gopikrishna V., Venkateshbabu N., Krithikadatta J., Kandaswamy D. Evaluation of the effect of MTAD in comparison with EDTA when employed as the final rinse on the shear bond strength of three endodontic sealers to dentine Australian Endodontic Journal.

[22] Behrend GD, Cutler CW, Gutmann JL. An in vitro study of smear layer removal and microbial leakage along the root canal fillings Int Endod J. 1996;29:99–107.

[23] García-Godoy F, Loushine RJ, Itthagarun A, Weller RN, Murray PE, Feilzer AJ, et al Application of

biologically oriented dentin bonding principles to the use of endodontic irrigants Am J Dent. 2005;18:281–90

[24] Keine KC, Kuga MC, Tormin FBC, Venção AC, Duarte MAH, Chávez-Andrade GM, Faria G. Effect of peracetic acid used as single irrigant on the smear layer, adhesion, and penetrability of AH Plus. Braz Oral Res. 2019 Jul 29;33:e057

[25] Kühlfluck I, Klammt J. [Suitability of peracetic acid for root canal disinfection]. Stomatol DDR. 1980 Aug;30(8):558-63.

[26] Zmener O, Spielberg C, Lamberghini F, Rucci M. Sealing properties of a new epoxy resinbased root-canal sealer. Int Endod J. 1997;30:332–4.

[27] Kandaswamy D, Venkateshbabu N, Arathi G, Roohi R, Anand S. Effects of various final irrigants on the shear bond strength of resin-based sealer to dentin. J Conserv Dent. 2011;14:40–2.

[28] Ungor M, Onay EO, Orucoglu H. Push-out bond strengths: the Epiphany-Resilon endodontic obturation system compared with different pairings of Epiphany, Resilon, AH Plus and gutta-percha. Int Endod J. 2006 Aug;39(8):643-7

[29] Dornelles-Morgental R, Guerreiro-Tanomaru JM, de Faria-Júnior NB, HungaroDuarte MA, Kuga MC, Tanomaru-Filho M. Antibacterial efficacy of endodontic irrigating solutions and their combinations in root canals contaminated with Enterococcus faecalis. Oral Surg Oral Med Oral Pathol Oral Radiol Endod. 2011 Sep;112(3):396-400.

[30] Lottanti S, Gautschi H, Sener B, Zehnder M. Effects of ethylenediaminetetraacetic, etidronic and peracetic acid irrigation on human root dentine and the smear layer. Int Endod J. 2009 Apr;42(4):335-43.

[31] Kovaleva J, Degener JE, van der Mei HC. Mimicking disinfection and drying of biofilms in contaminated endoscopes. J Hosp Infect. 2010 Dec;76(4):345-50.

[32] Kitis M. Disinfection of wastewater with peracetic acid: a review. Environ Int. 2004 Mar;30(1):47-55.

[33] Onay EO, Orucoglu H, Kiremitci A, Korkmaz Y, Berk G. Effect of Er,Cr:YSGG laser irradiation on the apical sealing ability of AH Plus/gutta-percha and Hybrid Root Seal/Resilon Combinations. Oral Surg Oral Med Oral Pathol Oral Radiol Endod. 2010 Nov;110(5):657-64.\

[34] Taneja S, Kumari M, Anand S. Effect of QMix, peracetic acid and ethylenediaminetetraacetic acid on calcium loss and microhardness of root dentine. J Conserv Dent. 2014 Mar;17(2):155-8.

[35] Aranda-Garcia AJ, Kuga MC, Vitorino KR, Chávez-Andrade GM, Duarte MA, BonettiFilho I, et al. Effect of the root canal final rinse protocols on the debris and smear layer removal and on the push-out strength of an epoxy-based sealer. Microsc Res Tech. 2013 May;76(5):533-7.

[36] Kokkas AB, Boutsioukis AC, Vassiliadis LP, Stavrianos CK. The influence of the smear layer on dentinal tubule penetration depth by three different root canal sealers: an in vitro study. J Endod. 2004 Feb;30(2):100-2

[37] Amara L, Shivanna V, Rajesh LV. Push-out bond strengths of the dentine – Sealer interface with and without a main cone: A comparative study using different sealers and cone systems. Endodontology. 2012;2:56–64.

[38] Gurgel-Filho ED, Lima FC, Saboia Vde P, Coutinho-Filho Tde S, Neves Ade A, da Silva EJ. Push-out bond strength of a self-adhesive resin cement used as endodontic sealer. Restor Dent Endod. 2014 Nov;39(4):282-7

[39] The efficacy of several endodontic irrigating solutions: a scanning electron microscopic study: part 2 Goldman, Melvin et al. Journal of Endodontics, Volume 8, Issue 11, 487 – 49

[40] Kim JS, Cho BH, Lee IB, Um CM, Lim BS, Oh MH, et al. Effect of the hydrophilic nanofiller loading on the mechanical properties and the microtensile bond strength of an ethanol-based one-bottle dentin adhesive. J Biomed Mater Res B Appl Biomater. 2005;72:284–91.

[41] Nabavizadeh M, Sobhnamayan F, Sedigh-Shams M, Liaghat S. Comparison of the push-out bond strength of AH Plus sealer to dentin after using different herbal irrigation solutions as the final rinse. PLoS One. 2022 Nov 2;17

[42] Baldissera R, Rosa RA, Wagner MH, Kuga MC, Grecca FS, Bodanezi A, et al. Adhesion of real seal to human root dentin treated with different solutions. Braz Dent J. 2012;23:521

[43] Paque F, Luder HU, Sener B, Zehnder M. Tubular sclerosis rather than the smear layer impedes dye penetration into the dentine of endodontically instrumented root canals. Int Endod J. 2006;39(1):18–25